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COATINGS OF POWDERED SUBSTANCES TECHNOLOGY OF COATING APPLICATI--ETC(U)
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COATINGS OF POWDERED SUBSTANCES TECHNOLOGY OF COATING APPLICATION

by

Jerzy Brzezinski

FOREIGN TECHNOLOGY DIVISION

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COATINGS OF POWDERED SUBSTANCES TECHNOLOGY
OF COATING APPLICATION

Jerzy Brzezinski

The ever higher requirements set for isolation and anti-corrosion coatings, especially in the electrotechnical and related industries, have increased the interest and research in the area of technology of applying coatings of powdered substances. In Poland these methods are not yet commonly used, but the trial applications and research have given results which encourage their wider use.

FLAME SPRAY

Numerous methods for applying coatings of powdered substances have been developed; depending on the requirements and the kinds of surfaces to be coated, the following methods are utilized: flame, fluidization, electrostatic or spray mist.
The flame spray consists in spraying the powdered substance onto the substrate through a zone of flame or in its vicinity, in order to create a uniform, dense and solid coat. Spraying is used primarily with large surfaces of metal. In order to form a coat by flame spraying one uses devices consisting of a spray gun, a container for the powdered substance (often with a vibrator), an installation with flammable gas, and an installation with pressurized air. The following gases are used as flammable gas: acetylene, liquid gas (a mixture of propane and butane), lighting gas or natural gas. Sometimes oxygen is also used in order to increase the temperature of the flame, but usually pressurized air is sufficient (100...300 kN/m^2 - appr. 1...3 at) and lighting gas, which gives flame temperature of 1200...1300°C.

The distance between the nozzle and the substrate for coating should be 60...100mm. The substance is then in the flame for several milliseconds, which is entirely sufficient for its melting without any distinct, undesirable thermal decomposition. The best results are obtained when coating is applied to sections of 500x500 mm rather than the entire surface. In order to obtain a coat of thickness 0.2-1 mm (usually seen in practice), it is necessary to apply 6-8 intermediate layers. Spraying of 1 m^2 of surface by a well trained worker takes on the average about 15 min, and about 1 kg of substance is used.

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This method is used most often to coat steel surfaces, but it may also be used to coat glass, ceramics, and even wood.

Considerable differences between the coefficients of thermal expansion for powdered substances and for metals cause contraction pressures, which in turn lead to the generation of layer separation and chipping of coating. In order to increase the attachment of the coating to substrate, the surface to be coated is heated to a appropriate temperature. Preheating the surface to be coated diminishes the contraction pressure as well as gives better layering of the coat.

The best results are obtained when continuous coating is applied over the entire object surface. One should avoid sharp edges and the edges of openings on which, because of contraction, the thickness of the coat is always lower, and sometimes is totally interrupted. The smallest acceptable radius of the curve is 4 mm. If the objects to be coated had been preheated to appropriately high temperature, one can also use flameless spraying, i.e. it is possible to spray cold powder over hot surface, on which it is melted. The results are poor over connections with screws, because air bubbles appear under the coating and cause a separation of coat layers.

FLUIDIZATION METHOD

In the fluidization methods the same powdered artificial substances are used as in flame spraying. Coating is obtained by immersing the object heated to an appropriate temperature (somewhat higher than the melting temperature of the substance used) in the fluidization zone, i.e. in the suspension of powder in a stream of flowing gas. A simple device serving this purpose is shown in Fig.1.

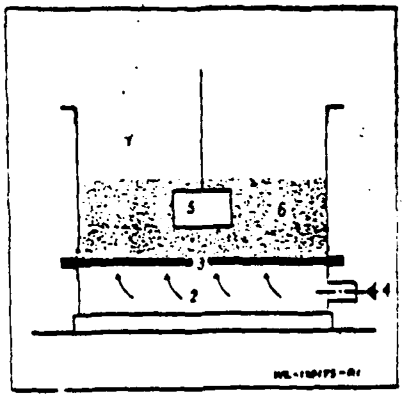


Fig.1. Diagram of a device for generating coatings by the fluidization method. 1-upper part of the bath; 2-lower part of the bath; 3-porous partition; 4-inlet of pressurized air; 5-object being coated; 6-whirling powder being liquefied (fluidization bed).

The gas (usually air) flowing through the layer of powder, liquefies it. The fluidization zone resembles a liquid in its appearance and properties, and the coating generated on the object is uniform and dense (Fig.2).

Fig.2. Coating of collecting belt in fluidization bath of epoxy powder Araldit.

The air pressure should be chosen such that laminar flow is obtained. Pressures used in practice are 100...600 kN/m^2 (appr. 1...6 at), depending on the size of the bath, and the amount of air necessary is then 1...60 m^3/hr.

If there is a large range of powder particle sizes and of the openings in the porous partition, and if air pressure is wrong or its flow is turbulent, there may be disturbances in the process of fluidization, such as segregation, generation of bubbles, separation of suspension layeres, channel formation or finally expulsion of powder from the bath.

Because of simple technology the fluidization method is one of the principal methods of isolation coating application in electrical and electrotechnical industry. It is used to coat collecting belts, rail wires, various construction-isolation parts and elements, and electrical subunits such as rheostats, condensers, switches etc.

In this method the appropriate granulation of the powder plays an important role, and the particle dimensions should be within 175-350 μm, which ensures uniform spraying. The contribution of each particle size should be the following: 0.3-0.15 μm - appr. 20%; 0.15-0.04 μm - appr. 60%; and below 0.04 μm - appr. 20%.

Indications for appropriate heating temperatures are contained in individual instructions and rules of use for the different types of powders commercially available.

Independently of this, it is necessary to establish every time experimentally the appropriate temperature and time of heating in order to prevent the generation of new oxide layers on the surface being coated, especially for metals and alloys.

The thermal conductivity of the coated material has an important effect on the time of heating, rapidity of caking and melting of the powder, as well as on the hardening of the surface. Metals such as copper and iron, which have relatively low specific heat, require a somewhat higher heating temperature to make the melting process rapid.

The rapidity of continuous coating generation decreases with the time of immersion of the object in fluidization bath; after a certain time it is stabilized and the process continues until the temperature of the surface being coated is equal to the temperature sufficient for melting further powder particles. Thus the thickness of the coating may be regulated within certain range depending on the time of the bath and the temperature of the part being heated, and usually falls within the range of 0.2...1.0 mm. Fig.3. shows the effect of time of immersion and of temperature of heating on the thickness of the epoxy coating Araldit.

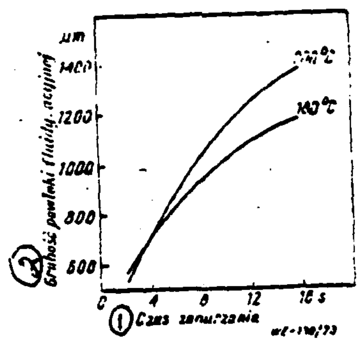


Fig.3. Effect of the time of immersion and of heating temperature on the thickness of fluidization coating made of epoxy powder Araldit(on a sample of iron sheet 1.5 mm thick). 1-time of immersion, 2-thickness of fluidization coating.

The surfaces and planes which are not to be coated should be covered with an appropriate protecting layer, before or after heating. Materials appropriate for this purpose include substances with low heat conductivity, such as silicone caoutchouc, azbestos, polyfluorocarbon compounds or self-adhesive teflon tape (produced by an american firm, E.J.duPont de Nemours Co.,Inc.). One can also use paper covered with aluminum foil or foil with glass fibers, e.g. Permasell P-212, produced by the swiss firm Permapack AG, Rorschach.

Fluidization coatings may be obtained from various polymers, but especially encouraging results have been obtained using epoxy resins. They are stable, they melt at a relatively low temperature of 100-120°C, and because of their high reactivity, the meshing occurs very rapidly at 120-200°C. Solidified coatings attach well to the substratum, are adequately resistant mechanically and in terms of heat, and resist the action of water and many chemicals.

ELECTROSTATIC FLUIDIZATION METHOD.

The principle of operation of electrostatic fluidization consists in adding an electric charge to the powder particles present in the fluidization bath and in immersing the grounded object in fluidization bed, i.e. in powder suspension. The powder is liquefied in a manner similar to that in an ordinary fluidization device, except that a metal net placed in the lower part of the bath charges the whirling powder particles. Other functions take place as in an ordinary fluidization bath. The source of high voltage current is provided by generators of direct current with operating voltage of 70-90 kV. The current intensity is very low and equals about 200 μA . Higher voltage is not used because of the danger of dust explosion.

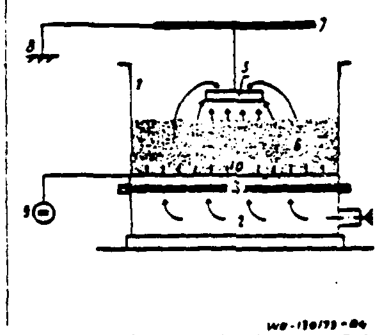
This method allows to obtain coatings on cold or slightly heated surfaces. The powder used for this purpose has low specific conductivity, high dielectric constant, low density, and possibly uniform particle size of 20-120 μm.

Each charged particle of powder, being a good isolator, loses at the temperature of the environment only a part of its charge on the charged surface of the object being coated. The remaining charge permits the attachment of the powder particle to the surface of the object being coated. Further particles fall onto surfaces not yet covered and attach similarly. When the coating of powder receives a charge of defined value, then, as a result of the same polarity, further powder particles will be repelled. This maintains a uniform thickness of the coating.

Raising the temperature of the part being coated affects favorably the process of the application of powdered coating and allows to generate stronger and better adhering layers of the substance. Powder particles undergo melting at the hot surface lose their charge completely. The parts covered with epoxy powder electrostatically must be processed by heat in order to melt the powder into a uniform, tight coating, and to harden it after melting.

Fig.4. shows a diagram of a device for electrostatic fluidization. The fluidization bath is made usually of an isolator substance and rests on shock absorbers connected to a vibrator.

Fig.4.Diagram of a device for electrostatic fluidization. 1-upper part of the bath, 2-lower part of the bath, 3-porous partition with strengthening device, 4-pressurized air inlet, 5-object being coated, 6-whirling, liquefied powder, 7-suspension, 8-grounding, 9-generator of high voltage, 10-electrodes.



This method is especially useful for rapid serial application of coating onto tapes and metal foil for reel isolation, onto wires, electrical elements and subunits, collecting rails and in all instances where the objects to be coated would have to be heated to very high temperatures if the classical fluidization methods were to be used.

THE METHOD OF ELECTROSTATIC SPRAYING.

The process of electrostatic spraying takes place in free space, using a specially designed spray gun. The device is composed of three main parts: the generator of direct current of high voltage, the spraying device, and a container for the powdered material. The voltage of the gun nozzle is 30...90kV, and its distance from the surface of the grounded object is 150...250 mm. The spraying is carried out using stationary or hand guns.

The voltage of the nozzle may be changed without intermediate steps, and higher voltage is used for coating of objects without screening spaces. The thickness of coating is within the range of 40 - 300 μm, and in practice of production one usually obtains coatings of thickness 80 - 100 μm. The thickness of the coating depends on the quantity of the powder being supplied to the gun nozzle, velocity of displacement of the gun, and to some extent on the voltage. It is possible to obtain thicker coating (0.5-1mm) either by preheating the object, special surface treatment (USSR patent 259305), consecutive spraying of layers with alternating polarity, or by using the nozzle without applying any voltage.

Spraying of deep objects, with screening surfaces, requires a change in the shape of the stream or in the voltage. A change in the shape of the stream is achieved, depending on construction, by changing the nozzle or by moving the pulverizing device with respect to the point of powder release. In the case of spraying objects with complex surface, usually bell-shaped rotating nozzles are used, whereas flat objects are sprayed by stationary nozzles.

Appropriate choice of the parameters of spraying, especially of the voltage, should be always adjusted for the kind of object, powder, and the requirements for the coating. With manual spraying it is difficult to obtain uniform thickness over the entire surface being coated, e.g. in depressions etc. Increased density of the lines of electrostatic field at the edges causes a thickening of the layers applied.

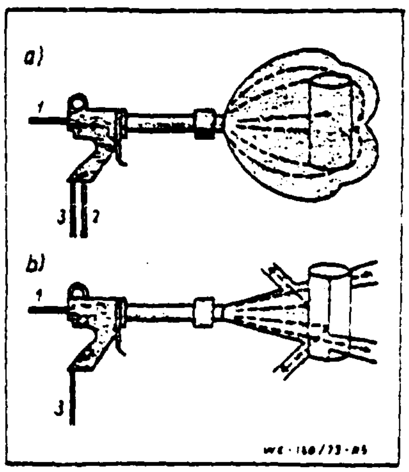


Fig.5.Electrostatic spraying: a-spraying with electrostatically charged powder; b-spraying with electrostatically inert powder. 1-pressurized air inlet; 2-connection to the high voltage generator; 3-powder inlet.

The method of electrostatic spraying is recommended for coating of objects which are difficult to process, have low heat capacity, complex shape and large surfaces. Similarly charged powder particles repel each other in transit and are deposited very evenly on the surface being coated. The intensity of the lines of electrostatic field, and therefore of the force acting on the transported particles are so great that the powder particles are deposited equally easily even on the opposite side of the object (Fig.5). Layers formed in this manner attach well to the cold surfaces and do not detach even under the stress of transport on automated conveyors. After the layer is applied the objects are heated to appropriate temperature in order to melt and solidify the coating. Using special recovery devices it is possible to reduce the losses of powder to about 1%. The pressurized air used for spraying should be very carefully dried and oils removed. If this rule is not followed, the cables may be clogged, supply to the spray gun may be disrupted, and defects may appear in the coating. The technique of coating is easy to master when appropriate parameters are selected. The danger of toxicity depends primarily on the kind of powder used and is minimal when the process is correctly carried out.

The method of electrostatic spraying has not been mastered yet in our country. A prototype of an electrostatic spray gun has been produced at the Institute of Precision Mechanics. Further studies on the improvement of its construction are under way, but serial production is not expected in the near future.

The METHOD OF MIST SPRAYING USING VENTURI NOZZLES.

The method of mist spraying (Fig.6) is used when the complex shape of the part or unit makes it difficult or impossible to apply other methods of electro-isolation protection. The most typical example of the use of this method is the isolation of the grooves of rotors and stands, packets of metal sheets, wire cores, toroidal cores, transformer parts etc.

The method of mist spraying consists in spraying of powder onto an object heated to appr.200-220°C (for an epoxy powder) by a set of nozzles of Venturi under slight pressure.

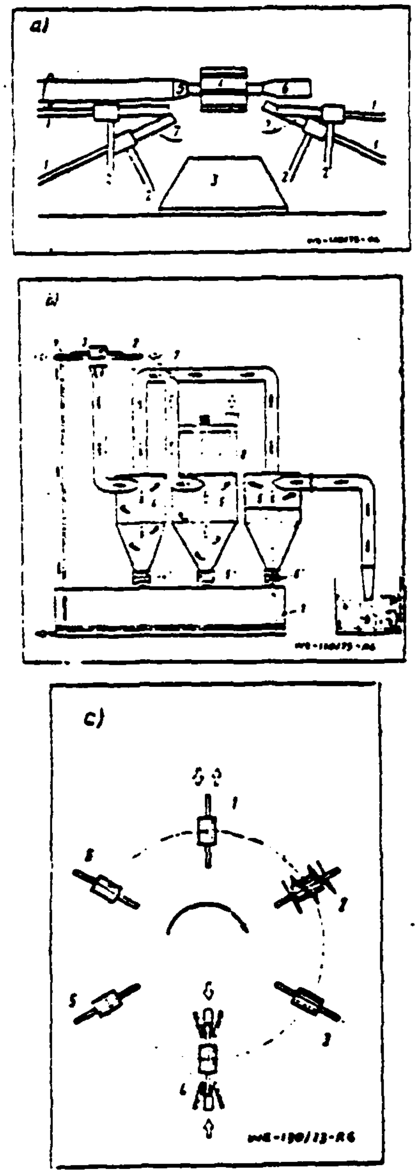


Fig.6.Mist spraying: a- principle of operation of a device for mist spraying. 1-pressurized air inlet, 2-powder inlet, 3-powder recovery, 4-object being coated(rotor), 5-rotary clamp, 6-post-axial coating, 7-spraying nozzles.

b-diagram of an installation for powder spraying. 1-bath with powder suspension, 2-Venturi nozzles, 3-powder recovery, 4,5-cyclone powder recovering devices, 4,5,6 - turbine blades,6-accessory supply,7-valve, 8-filter, 9-supply of powder taken up by suction.

c-steps carried out at a six-position table. 1-placing and removing the object, 2-(induction) heating of the object, 3-equalization of temperature, 4-spraying, 5- gelling, 6-hardening of the coating.

Fig.6. shows a diagram of a spraying installation. In container 1 the powder is liquefied (forming the fluidization bed). The powder is liquefied by air flowing under slight pressure from below through the porous bottom of the container. Using four Venturi nozzles (2 and 2'), the whirling powder is sucked up from the

suspension bath and is directed onto the rotating object 3, heated to appr.220°C. The powder particles coming in contact with the hot surface are melted into a uniform and smooth coating which gels within a short time and hardens. Excess powder is directed to container 1 by the cyclone recovery devices 4 and 5, which are equipped with turbine blades 4' and 5'.

When the level of powder in container 1 becomes lower, a photoelectric sensor causes an appropriate amount of powder from container 6 to be supplied by turbine blades 6'. Container 6 is filled directly from powder supply 9 by a suction device with valve 7 closed. In addition, a special rotating table is used in this process, shown in diagram 6c. In position 1 the object being coated is placed(removed); in position 2 the object is heated using a generator of intermediate or high frequency (induction heating); in position 3 equalization of temperature takes place; in position 4 the object is sprayed using Venturi nozzles; in position 5 gelling takes place, and in position 6 the coating is hardened.

The thickness of the coating is determined experimentally. It depends on the duration of spraying, the temperature to which the object is heated and the velocity of rotation of a given detail during coating. It also depends on the coating of edges; the thickness of the coating at the edges is 40-60% of the thickness of the coating obtained on flat surfaces, and the greatest stretching of wires during their winding occurs right at the edges.

Using this method it is possible to mask the parts which should not be coated with the help of air curtains. Compared to methods used until now in isolating rotors and stands, the method of mist spraying may be used in automated, serial production.

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